SPECIFICATION

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Cutter and Method of Manufacture Thereof

Cross Reference to Related Applications

This application is a Continuation-in-Part of U.S. Patent application serial number 10/064,428 filed on July 12, 2002 by Nigel Griffin.

Background of Invention

[0001] 1. Field of the Invention.

[0002] This invention relates to a cutter, and to a method of manufacture thereof. The invention relates, in particular, to a cutter suitable for use on a drill bit for the formation of subterranean well bores. It will be appreciated that the cutter may alternatively be used in other applications.

[0003] 2. Description of the Related Art.

[0004] One form of drill bit for use in the formation of subterranean wellbores comprises a bit body having a first end provided with a plurality of generally radially extending upstanding blades and a second end adapted to be secured to a drill string. Each of the blades carries a plurality of cutters. The cutters typically each comprise a tungsten carbide or other metallic substrate to which is bonded a layer of a superhard material, for example polycrystalline diamond. The substrate may be bonded directly to the bit body, or alternately may be bonded to a relatively long substrate which, in turn, is secured to the bit body.

[0005]

In another form of drill bit, cutters are mounted upon rotatable cones mounted upon a bit body. Each cutter is typically manufactured by placing a sintered tungsten carbide substrate and diamond crystals into a container with a suitable binder catalyst

material, and subjecting the container to high pressure, high temperature conditions such that the diamond crystals bond to one another and to the substrate.

[0006] A number of different designs of cutter are known, the different designs arising from, for example, the use of substrates of different shapes. In one example, the substrate includes an upstanding peripheral wall extending around most, but not all of the circumference of the substrate. A cutter manufactured using a substrate of this shape includes a polycrystalline diamond table which only extends to the periphery of the cutter at the region where the peripheral wall is absent as shown in Figures 1 and 2. It has been found that in cutters of this type there is a tendency for the polycrystalline diamond table to crack. This is thought to be as a result of hoop stresses.

[0007] A number of cutter designs provide the cutter with two or more cutting surfaces. This is achieved, in some designs, by providing two separate substrates, a first diamond layer located between the substrates and a second, isolated diamond layer located upon the second substrate. This type of cutter is shown in US Patent No. 5,722,499 and US Patent No. 5,667,028, both incorporated by reference herein for all they disclose. Another design includes separate diamond layers formed by providing grooves in the outer periphery of the substrate and introducing diamond crystals into the grooves prior to undertaking the high temperature high pressure process. Cutters of this type are illustrated in US Patent No. 5,979,578 and US Patent No. 5,667,028, both incorporated by reference herein for all they disclose. It will be appreciated that, in these arrangements, two or more independent, isolated regions of polycrystalline diamond are formed.

Summary of Invention

[0008] The present invention provides a cutter with a reduced tendency for the polycrystalline diamond table to crack, and a method for manufacture of such a cutter.

[0009]

According to the present invention there is provided a method of manufacturing a cutter comprising assembling a first substrate component, a second substrate component and diamond crystals into a desired configuration, and subjecting the

assembly to high temperature and high pressure conditions to cause the diamond crystals to bond to one another and to the first and second substrate components to form a cutter having a single body of polycrystalline diamond.

[0010] The first and second substrate components may be arranged to engage one another, or alternatively may be separated from one another by at least some of the diamond crystals prior to subjecting the assembly to high temperature, high pressure conditions.

[0011] The first and second substrate components are preferably of sintered tungsten carbide form. However, this need not be the case and other materials could be used. For example the second substrate component could be of a STELLITE (R) material. A binder catalyst material, for example cobalt, may be included in the assembly. Although cobalt is the preferred binder catalyst material, other iron group elements may be used, if desired. The binder catalyst material may be included in either of the first and second substrate components, or mixed with the diamond powder, or provided in any combination of these locations.

[0012] Also disclosed is a cutter with a single diamond table bonded to first substrate component of circular cross-section and to a second substrate component of annular or part-annular form. At least one further substrate component, for example of annular or part annular form, may additionally be provided.

[0013] According to another aspect of the invention there is provided a method of forming an assembly by locating a powdered substrate component material, diamond crystals and a first substrate component within a container in a desired configuration, and subjecting the assembly to high temperature and high pressure conditions to cause the powdered substrate component material to form a second substrate component, and the diamond crystals to bond to one another and to the first and second substrate components to form a cutter having a single body of polycrystalline diamond.

[0014] The powdered substrate component material is preferably powdered tungsten carbide. As mentioned hereinbefore, a binder catalyst material may be provided, for example mixed with the powdered substrate component material.

[0015] The configuration of the powdered substrate component material within the assembly may be such as to result in the formation of at least one additional substrate component. The second and/or additional substrate components may be of annular or part-annular form.

[0016] The invention also relates to a cutter manufactured using either of the methods described hereinbefore.

[0017]

Brief Description of Drawings

[0018] The invention will further be described, by way of example only, with reference to the accompanying drawings.

[0019] Figure 1 is a diagrammatic sectional view of a prior art cutter.

[0020] Figure 2 is an end view of the prior art cutter of Figure 1.

[0021] Figure 3 is a perspective view of a drill bit.

[0022] Figure 4 is a perspective view of an alternative drill bit.

[0023] Figures 5 and 6 are views similar to Figures 1 and 2 showing a cutter in accordance with an embodiment of the invention.

[0024] Figure 7 is a diagrammatic view illustrating part of the manufacturing operation.

[0025] Figures 8 to 25 are cross-sectional and side views of other embodiments.

[0026] Figure 26 is a view similar to Figure 7 illustrating an alternative manufacturing technique.

[0027] Figure 27 is a view of one orientation of the notches on the second substrate components.

[0028] Figure 28 is a view of a second orientation of the notches on the second substrate components.

[0029]

Figure 29 is a partial view of an enlargement of the second substrate components

showing a configuration of a notch.

Detailed Description

[0030] Referring now to Figure 3 there is shown a drill bit for use in the formation of subterranean wellbores. The drill bit comprises a bit body 10 having a first end 12 upon which a plurality of blades 14 are provided, the blades 14 upstanding from the first end 12 and extending in generally radial directions. The bit body 10 further includes a second end 16 adapted to permit the drill bit to be secured to the remainder of a drill string whereby the drill bit can be driven for rotation about its longitudinal axis 18. Each of the blades 14 is provided with a plurality of cutters 20, each of the cutters 20 being arranged to engage the formation being drilled using the drill bit, in use, such that the combination of rotation of the drill bit and the application of a load, in a generally axial direction, upon the drill bit causes the cutters to scrape the material from the formation. The drill bit further includes a plurality of nozzles 22 supplied with fluid and arranged such that, in use, fluid supplied through the nozzles 22 serves to clean the cutters and to carry the material removed by the cutters away from the drill bit.

[0031] As is common practice with drill bits of this type, the drill bit includes a gauge region 24. In the arrangement shown, the gauge region 24 is provided with a plurality of inserts 26 intended to enhance the ability of the drill bit to withstand wear of the gauge region.

[0032] Figure 4 illustrates an alternative type of drill bit. In the drill bit of Figure 4, the bit body 110 has an upper portion 116 which form legs 124 shaped to define mounting regions which in turn carry rotatable rollers 128 of generally conical form. Each of the rollers 128 is provided with a plurality of cutters 120. As with the drill bit illustrated in Figure 3, in use, the drill bit of Figure 4 is rotated about its axis 118. With the drill bit of Figure 4, such rotation causes the rollers 128 to rotate about their own axes, this movement causing the cutters 120 to engage and scrape against the formation being drilled to remove material therefrom which, as in the arrangement illustrated in Figure 3, is removed by the application of drilling fluid. Similar to the drill bit of figure 3, gauge inserts 126 are also provided.

[0033] Cutters 20, 120 may have various shapes and sizes as shown. However, for ease of understanding, the references and explanations for cutters 20 in this specification apply equally to cutters 120, as both types may be useful in both types of drill bits shown. The cutters 20, 120 may also be useful in numerous other type of down hole tools and other devices employing highly wear resistant cutting elements.

[0034] Figures 5 and 6 illustrate one of the cutters of the drill bits shown in Figures 3 and 4. The cutter 20 shown in Figure 5 comprises a first tungsten carbide substrate component 30 of generally cylindrical form, a second substrate component 32, also of tungsten carbide, and of part-annular form as shown in Figure 6, and a polycrystalline diamond table 34. The cutter 20 is manufactured by placing the second substrate component 32 into part of a suitable container 36, positioning powdered diamond crystals 34a in the region in which the table 34 of polycrystalline diamond is to be formed, and positioning the first substrate component 30 onto the second component 32 and diamond crystals 34a. The container 36 is then closed and sealed, as shown in Figure 7, the assembly then being subjected to high temperature, high pressure conditions to cause the diamond crystals 34a to bond to one another and to the first and second substrate components 30, 32. It will be appreciated that the formation of such bonds results in the production of the polycrystalline diamond table 34. In order for the table 34 of polycrystalline diamond to form, the assembly shown in Figure 7 may further include a quantity of a suitable binder catalyst material. Typically, the binder catalyst material takes the form of cobalt. However, a number of other materials could be used. In particular, any iron group element may be used as the binder catalyst material. The binder catalyst material may be introduced into the assembly by mixing the binder catalyst material with the diamond crystals 34a, or by incorporating the binder catalyst material into one or other, or both of the first and second substrate components 30, 32, or by including the binder catalyst material in the material of the container 36, or by a combination of these techniques. Where the binder catalyst material is included in the substrate components, it will be appreciated that it infiltrates into the diamond material during the high pressure high temperature operation.

[0035] After completion of the high temperature, high pressure sintering operation, the container 36 is removed and the cutter subjected to a suitable machining operation, if

desired.

[0036] It will be appreciated that the cutter 20 manufactured using this technique and as shown in Figures 5 and 6 is similar in appearance to the known cutter shown in Figures 1 and 2. However, the use of the two-part substrate results in the application of significantly lower magnitude hoop stressing to the polycrystalline diamond table, the separate second substrate component 32 being more compliant than arrangements in which a single substrate is used, and as a result the risk of cracking of the polycrystalline diamond table is significantly reduced.

[0037] Although the technique described hereinbefore with reference to Figures 5, 6 and 7 can be used to produce a cutter 20 which is similar to that of Figures 1 and 2, the same technique may be used to manufacture a wide range of other cutter designs. A number of possible cutter designs are shown in Figures 8 to 19. In the arrangement illustrated in Figures 8 and 9, the first and second substrate components 30, 32 are spaced apart from one another by a part of the polycrystalline diamond table 34. It will be appreciated that a cutter of this type may be produced simply by positioning the second substrate component 32 within one part of the container 36, introducing the diamond crystals 34a into the container 36, the diamond crystals 34a extending over the second substrate component 32, and then introducing the first substrate component 30 so that diamond crystals 34a are located between the substrate components 30, 32. The application of high pressure, high temperature conditions to such an assembly will result in the production of a cutter 20 of the type shown in Figures 8 and 9.

[0038] The prior cutters shown in Figures 1 and 2 have an overall impact toughness averaging about 30 joules. Cutters 20 manufactured as described, with the second substrate component 32 as shown in Figures 5, 6, 7 and 9 have demonstrated a 30% (to about 40 joules) improvement in impact toughness and accompanying reduction in cracking of the diamond table compared to the prior cutters shown in Figures 1 and 2. A still further improvement is obtained when notches 33 are pre-formed in the second substrate component 32, as shown in Figures 27-29.

[0039] The notches 33 allow the second substrate component 32 to crack in a controlled manner during processing, allowing additional relief of the stresses in the diamond

table 34. Providing these notches 33 for additional stress relief has resulted in an additional 25% (to about 50 joules) improvement in impact toughness over the cutters 20 made with un-notched second substrate components 32. Stated differently, the second substrate component 32 with the notches 33 have a 60% improvement in impact toughness over the prior cutters shown in Figures 1 and 2.

[0040] The notches 33 are formed into the second substrate component 32 either during its manufacture or the notches 33 are formed later by removing a portion of the material of the second substrate component 32. The notches may be regularly spaced, as shown in figures 28 and 29 or they may be irregularly spaced according to the size and orientation of the second substrate component 32. The notches may be shaped with rounded ends 35 as shown in Figure 29, or may have a variety of end configurations. The exact orientation of the notches is not particularly important, provided they provide a predictable path for the expansion of the second substrate component 32 during processing. This expansion often, but not necessarily always, leads to the aforementioned crack in the second substrate component 32 of the finished cutter 20 from the base of the notch 33 to the edge.

[0041] Accordingly, the method for manufacturing the cutters 20 comprising a first substrate component 30 and a second substrate component 32 for this embodiment of the invention is providing one or more notches in the second substrate component 32 and assembling the first substrate component 30 and the second substrate component 32 and diamond crystals 34a into a desired configuration, and subjecting the assembly to high temperature and high pressure conditions to cause the diamond crystals 34a to bond to one another and to the first and second substrate components 30, 32 to form a cutter 20 having a single body of polycrystalline diamond 34.

[0042]

Figures 10 and 11 illustrate a cutter 20 which is similar to that of Figures 8 and 9 but in which an additional, third substrate component 38 is located between the first and second substrate components 30, 32. In this arrangement, the polycrystalline diamond table 34 extends between the first and third substrate components 30, 38 and between the third and second substrate components 38, 32. The manufacturing process used in the formation of a cutter 20 of this type simply requires the introduction of the second substrate component 32 into the container 36, the

application of diamond material into the container 36 covering the second substrate component 32, the introduction of the third substrate component 38 into the container 36, the application of more diamond material to cover the third substrate component 38, and finally the introduction of the first substrate component 30.

[0043] The arrangement shown in Figures 12 and 13 is similar to that of Figures 10 and 11 but includes a fourth substrate component 42. A further distinction between the arrangement of Figures 12 and 13 and that of Figures 10 and 11 is that no diamond material is provided between the various substrate components. It will be noted from Figures 11 and 13 that in each of these arrangements, the angular extent of the various part-annular substrate components are not equal resulting in the formation of steps in the polycrystalline diamond table 34. This need not be the case. The arrangement of Figures 10 and 11 further differs from that of Figures 12 and 13 in that, as shown in Figure 12, the various part-annular substrate components are of non-equal radial extent whereas in the arrangement shown in Figure 10, the second and third substrate components 32, 38 are of equal radial extent.

[0044] Turning to the arrangement shown in Figures 14 and 15, the second and fourth substrate components, 32, 42 are of equal radial extent and equal angular extent, the third substrate component 38 being of smaller radial and angular extent with the result that the polycrystalline diamond table 34 includes a radially extending projection 34b around part of its periphery.

[0045] The arrangement shown in Figures 16 and 17 is similar to that of Figure 8, but differs therefrom in that the second substrate component 32 is not located at the surface of the cutter, but rather is buried within the polycrystalline diamond table 34.

[0046] In each of the arrangements described hereinbefore, the first substrate component 30 is of generally cylindrical form having a flat surface to which the other substrate components and/or the polycrystalline diamond table 34 is bonded. This need not be the case, and Figures 18 and 19 illustrate an arrangement in which the surface of the first substrate component 30 is grooved. As a result, an arrangement is possible in which in some areas of the cutter 20, the second substrate component 32 rests directly upon the first substrate component 30, and in other regions thereof the second substrate component 32 is spaced from the first substrate component 30. In

the regions where the second substrate component 32 is spaced from the first substrate component 30, as shown in Figure 19, then the polycrystalline diamond table 34 extends between the first and second substrate components, 30, 32.

[0047] In each of the arrangements described hereinbefore, it is important to note that the polycrystalline diamond table 34 is in the form of a single element, rather than taking the form of two or more separate components spaced apart and isolated from one another by a component of the substrate.

[0048] Although the cutters 20 described hereinbefore are suitable for use with drill bits of the type illustrated in Figure 3, it will be appreciated that by appropriate selection of the shape of the cutter, similar cutters may find application in drill bits of the type illustrated in Figure 4. A cutter 20 more applicable for use in a drill bit of the type illustrated in Figure 4 is shown in Figure 20.

[0049] The cutter 20 shown in Figure 20 comprises a first tungsten carbide substrate component 30 of generally cylindrical form but having a domed upper surface 50, in the orientation illustrated. A second substrate component 32 of annular form is positioned upon the first substrate component 30, the space within the second substrate component 32 containing a polycrystalline diamond table 34. The shapes of the second substrate component 32 and polycrystalline diamond table 34 are such as to define a domed surface 52. It will be appreciated that this type of cutter can be manufactured using a technique very similar to those described above.

[0050] It will be appreciated that a number of modifications can be made to the cutter of Figure 20, for example to change its shape so that the surface 52 is of, for example, generally conical form. Other variations include spacing the second substrate component 32 from the first substrate component 30, as shown in Figure 21, or including additional substrate components, as shown in Figure 22. The second and/or additional substrate components may be of annular or part-annular form. Where they are of curved, part-annular, form then depending upon their circumferential extent, two or more components may be provided at the same axial position as shown in Figure 23.

[0051]

With cutters of the type used on drill bits of the type shown in Figure 4, it is

common to provide one or more transition layers comprising a mixture of diamond and tungsten carbide between the tungsten carbide substrate and the polycrystalline diamond table. Such transition layers 54 may also be incorporated into the cutters shown in Figures 20 to 23. The second substrate component may be positioned upon the transition layer 54 or layers, for example as shown in Figure 24, or the transition layer 54 or layers may be at least partially encircled by the second substrate component, for example as shown in Figure 25.

[0052] In each of the arrangements described hereinbefore, the second and additional substrate components are of pre-sintered tungsten carbide form. It will be understood the other materials may be used, if desired. Where pre-sintered tungsten carbide substrate components are used, during the high pressure high temperature sintering operation the diamond will typically be compressed to a greater extent than the pre-sintered substrate components. This may result in, for example, a significant machining operation being required to produce a cutter having a flat or smooth face. It is thought that this effect may be reduced by modifying the manufacturing technique so that, instead of locating a pre-sintered second substrate component 32 with the container 36, and where appropriate instead of using pre-sintered third and fourth substrate components 38, 42, etc., a quantity of powdered tungsten carbide 56 is positioned in the container 36, as shown in Figure 26, in the areas in which the second substrate component 32, and where applicable the third and fourth substrate components 38, 42, etc., are required.

[0053] Once assembled, the application of the assembly to the high temperature, high pressure conditions will cause the second substrate component 32, and the third and fourth components 38, 42, etc., where applicable, to form as well as resulting in the formation of the polycrystalline diamond table and the bonding of the table to the first substrate component 30 and to the newly formed substrate components 32, 38, 42. As in the arrangements described hereinbefore, a binder catalyst material, typically cobalt, may be provided. The binder catalyst material may be mixed with the diamond powder, the tungsten carbide powder, the pre-sintered first substrate component 30, or in any combination of these locations.

[0054]

During the manufacturing operation, the tungsten carbide forming the second

substrate component 32 and, where appropriate, the additional substrate components, compresses at a rate similar to the powdered diamond with the result that a short, less complex machining operation may be required to produce a cutter with a generally flat or smooth surface.

[0055] It will be appreciated that this technique may be used in the manufacture of any of the cutters 20 described hereinbefore, or modifications thereto.

[0056] Again, as previously described, in all the embodiments described herein any of the secondary substrate components 32, 38, 42 which are performed may be provided with notches 33 to further improve impact toughness.

[0057] Whereas the present invention has been described in particular relation to the drawings attached hereto, it should be understood that other and further modifications apart from those shown or suggested herein, may be made within the scope and spirit of the present invention.